Characterization and Analysis of Europium Sulphide (EuS) Thin Films

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Abstract

Deposition of Europium Sulphide (EuS) thin films on bare glass substrates via spray pyrolysis method in an optimized aqueous bath environment. Structural characterization was carried out to determine the optimal deposition conditions. The results indicated that the optimum temperature for depositing high-quality EuS thin films is 623 K. At this temperature, the films exhibited excellent crystallinity, as evidenced by sharp X-ray diffraction (XRD) peaks. This confirms that 623 K is ideal for forming well-crystallized EuS thin films. These findings are significant for applications requiring high-quality crystalline structures and demonstrate that the spray pyrolysis method, when operated under optimized conditions, can effectively produce EuS thin films with superior structural properties.

Keywords: Europium sulphide, spray pyrolysis, X-ray diffraction, substrate temperature, crystallinity, semiconductor devices.
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Introduction

The europium chalcogenides EuO, EuS, EuSe, and EuTe are extensively studied materials. Glass substrates receive the deposition of Europium sulphide (EuS) thin film by adjusting precursor concentration and substrate temperature, using equal stoichiometric volumes of hydrous and anhydrous precursor solutions. Europium (III) chloride hexahydrate ($EuCl_3.6H_2O$) and thioacetamide (C_2H_5NS) serve as sources of europium and sulphur, respectively, to produce Europium sulphide (EuS) thin films. A deposited sample was then analysed for its morphology, structure, and other characteristics [1-6].

Method

Europium sulphide (EuS) thin films are deposited onto glass substrates using both hydrous and anhydrous solution baths. These baths are made from Europium (III) chloride hexahydrate ($EuCl_3{\cdot}6H_2O$) and thioacetamide (C_2H_5NS), each dissolved separately in deionized water and methanol, with equal stoichiometric volumes of 1:1. The aqueous solution of $EuCl_3$ and C_2H_5NS is thoroughly stirred using magnetic stirrer equipment at a rate of 550 rpm for 45 minutes to ensure homogeneity.

The deposition process begins with cleaning the substrates to ensure their pristine condition. Experimental substrates must be free of common contaminants such as grease, airborne dust, lint, and oil particles, as their presence can adversely affect the morphology of deposited films. Glass substrates undergo a rigorous cleaning process, which requires soaking them in a Chronic acid solution with a molarity of 0.5. for a duration of five minutes, followed by cleaning with dilute hydrochloric acid and standard laboratory detergent. Additionally, the substrates undergo ultrasonic cleaning with double-distilled water. Before deposition the substrates were meticulously dried using alcohol vapor for a duration of ten minutes [7-10].

$EuCl_3{\cdot}6H_2O$ and C_2H_5NS, used in the experiment, were sourced from Sigma Aldrich and were of analytical reagent (AR) quality grade, sourced from, Pune.

For atomization of the precursors, we employed the Spray Pyrolysis equipment using air as the gaseous medium. The nebulizer was equipped with a 'metal spray head' and a sharp needle-tip nozzle. The films produced had a subtle brownish tint.

Data related to the synthesized europium sulphide samples, prepared under optimized conditions, can be found in Table 1 below.

Table 1: EuS thin film samples that have been synthesized

Sample	Precursor Medium	Normality Eu^{3+} + $3Cl^{-}$ C_2H_5 + N + S. in M	Surface Temperature range in K
A	Aqueous	0.01/0.01	(a)548, (b) 573 (c)598, (d) 623
B		0.01/0.05	

The optimized preparation conditions for Europium sulphide (EuS) thin films are as follows:

• Initial Ingredients: EuCl3, C2H5NS, H2O

• Substrate Temperature: 573 K

• Precursor Concentration: 0.01 M

• Composition: 50:50

• Spray Nozzle: Metal needle.

• Spray Rate: 2 ml/min.

• Distance Between Nozzle and Substrate: 15 cm

• Carrier Gas: Air

• Gas Pressure: 3 psi

Investigating Europium Sulphide Thin Films Through X-ray Diffraction

Structural characterizations play a critical role in ensuring the reliability and efficiency of electronic components. Upcoming publications will present an analysis of the properties of materials deposited on substrate samples, with key findings emphasized.

The attribute of the deposited material is notably influenced by variations in the volumetric ratio of experimental precursors, providing an effective approach for managing these properties. To optimize the EuS volume ratio, films were prepared using different ratios: 90 to 10, 80 to 20, 70 to 30, 60 to 40, 50 to 50, 40 to 60, 30 to70, 20 to 80, and 10 to 90 respectively. By using a precursor solution concentration of 0.01 M, we coated these films at a surface temperature of 573 K, a spray rate of 2 ml/min, and a pressure of 3 psi.

Structural characterization was performed using X-ray diffraction (XRD) with a MiniFlex2 diffractometer, operating at Cu/30 kV/15 mA and utilizing kα radiation (wavelength λ = 0.1542 nm). The XRD patterns for the spray-deposited EuS films, labelled as samples A, B, C, and D, are shown in diagram 4.5 - 4.8. The diffraction peaks observed in the films correspond to 2θ values of 25.780°, 29.920°, and 42.460°, which align with the hkl planes (111), (200), and (220), respectively.

Discussion

Structural analysis: The X-ray diffraction (XRD) patterns for the spray-deposited EuS films, labelled samples A, B, C, and D, are presented in diagram. These patterns indicate that the films have a polycrystalline structure with a cubic, face-centred lattice arrangement. The diffraction peaks observed correspond to specific atomic distances within the crystal lattice.

The XRD peaks were indexed, and the inter-planar spacings (d_o) were analysed and matched against the reference values from Joint Committee on Powder Diffraction Standards card No. 75-0868.

The optimal deposition temperature for producing high-quality EuS thin films has been established at 623 K. The films display well-defined crystallinity, evidenced by sharp X-ray diffraction peaks, confirming that 623 K is ideal for producing well-crystallized thin films.

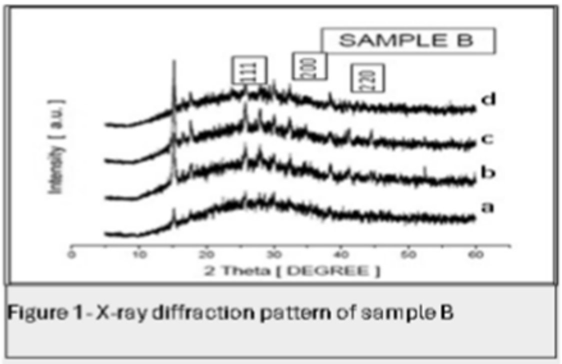

Figure 1: XRD of samarium ferrite obtained after different annealing time

Conclusion and Future Prospective

In conclusion, the study demonstrates a direct correlation between substrate temperature and the crystal quality of the coated EuS thin films. As the surface temperature increases from 548 K to 623 K, there is a clear improvement in the crystal structure of the films. An enhancement in film quality is corroborated by a mean particle size of 16.18 µm, demonstrating the effective formation of well-crystallized EuS films. The crystallite sizes were largest in films coated at temperatures exceeding 623 K.

Additionally, the study found that film thickness varies with substrate temperature. Films grown under 573 K exhibited reduced thickness, likely due to insufficient decomposition process of the precursor elements. In contrast, increased thickness was observed in films formed at temperatures higher than 573 K. suggesting complete decomposition. These results underscore the importance of substrate temperature in optimizing both the crystallinity and the performance of EuS thin films in semiconductor applications is highly dependent on their thickness.

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